



Optical Sensor based Microfluidic Lab-on-a-chip for Glucose Continuous Sensing

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Abstract

In this poster, a microfluidic lab-on-a-chip based on optical glucose sensing for continuous glucose monitoring is reported. It collects biological sample, mixes it with buffer fluid or test chemicals, and then it drives it toward the optical sensor for glucose sensing. The optical sensor consists of a reaction chamber aligned with input and output fibers. Lights transmitting through the reaction chamber interact with the glucose molecules and change its property. By sensing the light from output fiber, the glucose level in the sample can be derived. The lab-on-a-chip system also has self-flushing function to clean the chamber after each test, so that it can be ready for the next testing cycle. The function of the proposed lab-on-a-chip is verified with COMSOL simulation. The device can be used for low-cost continuous glucose monitoring.

Introduction

The lab-on-a-chip is a device that can realize multiple laboratory functions on a single chip with small scale. LOC is closely related to microfluidics which describes primarily the physics, the manipulation and study of minute amounts of fluids. The world's diabetic patients has increased significantly in recent decades. Diabetes has become a serious global health threat. Diabetic patients need to monitor their body glucose level on daily basis. Traditional blood-based glucose test causes pain and infection risk to patients. Painless continuous glucose sensing has been in pressing need for a long time. Traditional way usually use blood as the material to measure the concentration of the glucose for patients, in order to realize the painless measurement, saliva can be used in stead of blood. The material is easy to obtain. Optical glucose sensing has the advantage of low-cost, no infection risk and it may lead to continuous painless glucose sensing. Optical sensors for continuous glucose sensing have been reported. This lab-on-a-chip device integrates the function of transmitting the solution to the reaction chamber, using SPR optical sensor to measure the glucose concentration, flushing the chamber so that it can be reused next time to achieve the function of continuous glucose monitoring.

Lab-on-a-chip Design

In this poster, a silicon-based lab-on-a-chip device is presented. The device is 1.2cm X 1.2cm. As is showed in Fig.1, the design of the LOC consists of two micropumps, a Y model to transmit the glucose solution to the reaction chamber, and a reaction chamber with two SPR optical sensor fibers then it goes to a waste collection.

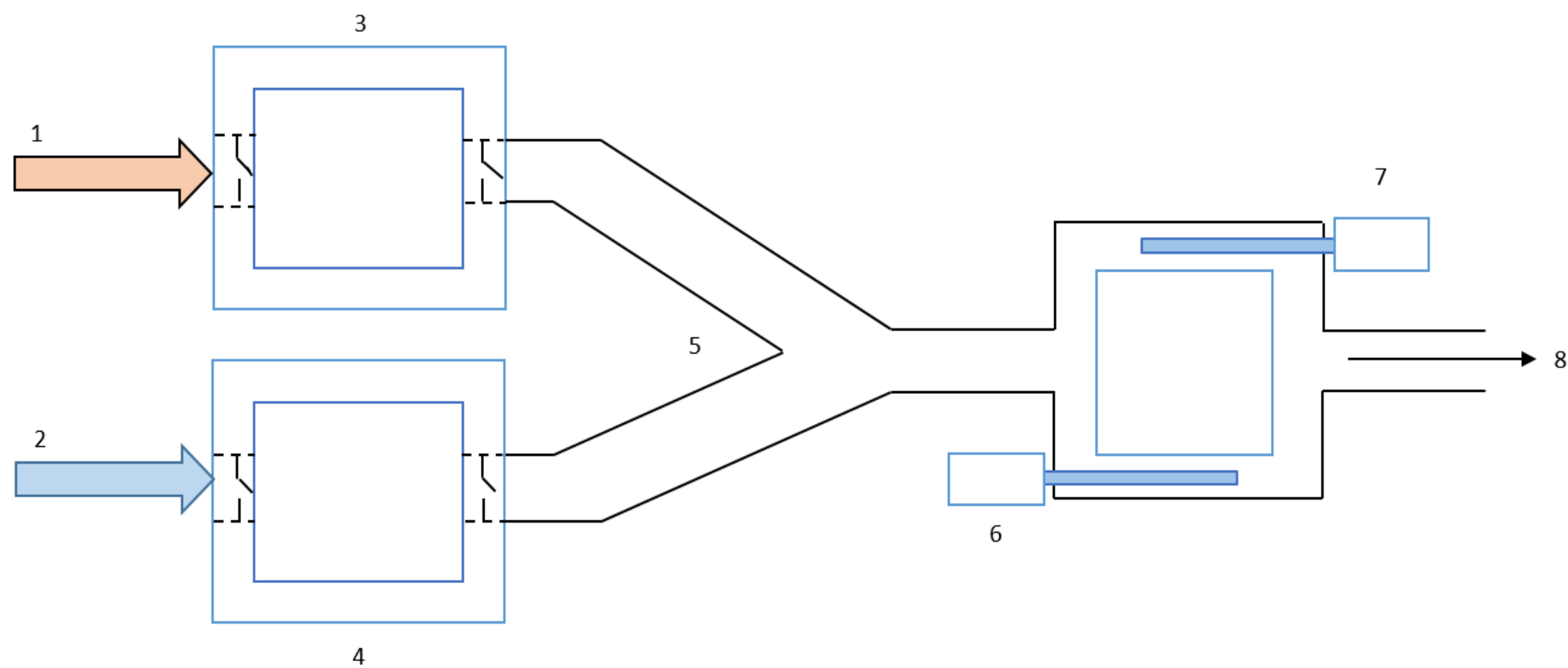


Figure 1:Schematic diagram of Lab-on-a-Chip device for glucose continuous sensing. In this figure, 1-2: glucose solution, water loading area; 3-4 piezoelectric micropump; 5: microchannel; 6-7: SPR optical sensor; 8: waste collection.

Working Principle

The working principle of the lab-on-a-chip system overview is presented as below. For glucose sensing, the saliva sample of patients are collected and delivered to the glucose solution loading area. Then the piezoelectric micropump pump the glucose solution to the microchannel and flow into the reaction chamber. In the reaction chamber, there are two fiber-optic surface plasmon resonance (SPR) glucose sensor are utilized to measure the glucose concentration of the sample. After finishing the glucose measurement, the water is loaded through the micropump. The water clean the channel and reaction chamber so that the device is ready for next working cycle. The working principle of fiber-optic SPR sensor is showed as below.

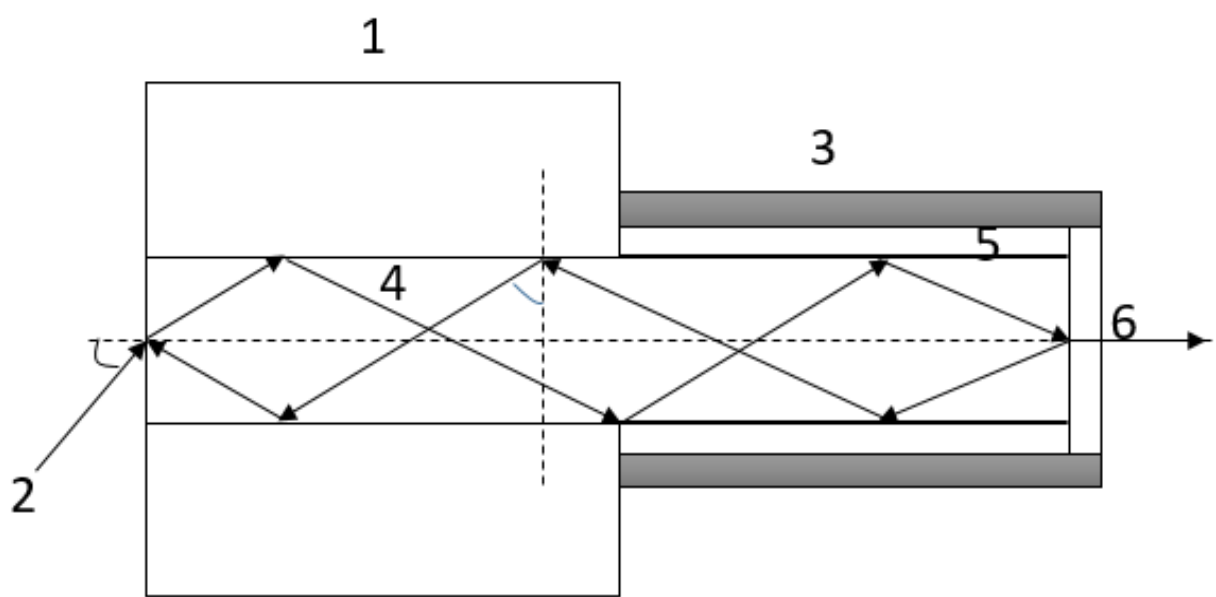


Figure 2:Schematic diagram of the fiber-optic SPR sensor for glucose concentration measurement. In the figure, 1 coating layer and the cladding layer; 2 Incident light; 3 Glucose solution; 4 Core; 5 Cr; 6 Micromirror.

When the white light source travel into the optical core, the internal total reflection happened with different reflection angles, and propagates forward. When the horizontal component of evanescent wave vector is equal to the surface plasmon wave vector at the interface between gold film and glucose solution, surface plasmon resonance occurs, resulting in a sharp attenuation of the reflected light energy. The SPR optical sensor can be equivalent to the superposition of multiple prism SPR reflection. When a wave length component meets the condition of exciting SPR, the SPR phenomenon will be generated at the interface between the core and film.

The total reflectivity of fiber-optic SPR reaches the minimum where the wavelength is called resonance wavelength. It is sensitive to the changes of glucose concentration in solution on the surface of the gold film.

COMSOL Simulation

The function of the proposed lab-on-a-chip is verified with COMSOL simulation. The structure of the device is simulation in COMSOL shown as below. It contain solution inlet on each micropump, after using fiber-optic SPR senses the concentration of glucose solution, the water start to flow in the device to flushing the chamber in order to prepare for next work cycle. The simulation results are present as below.

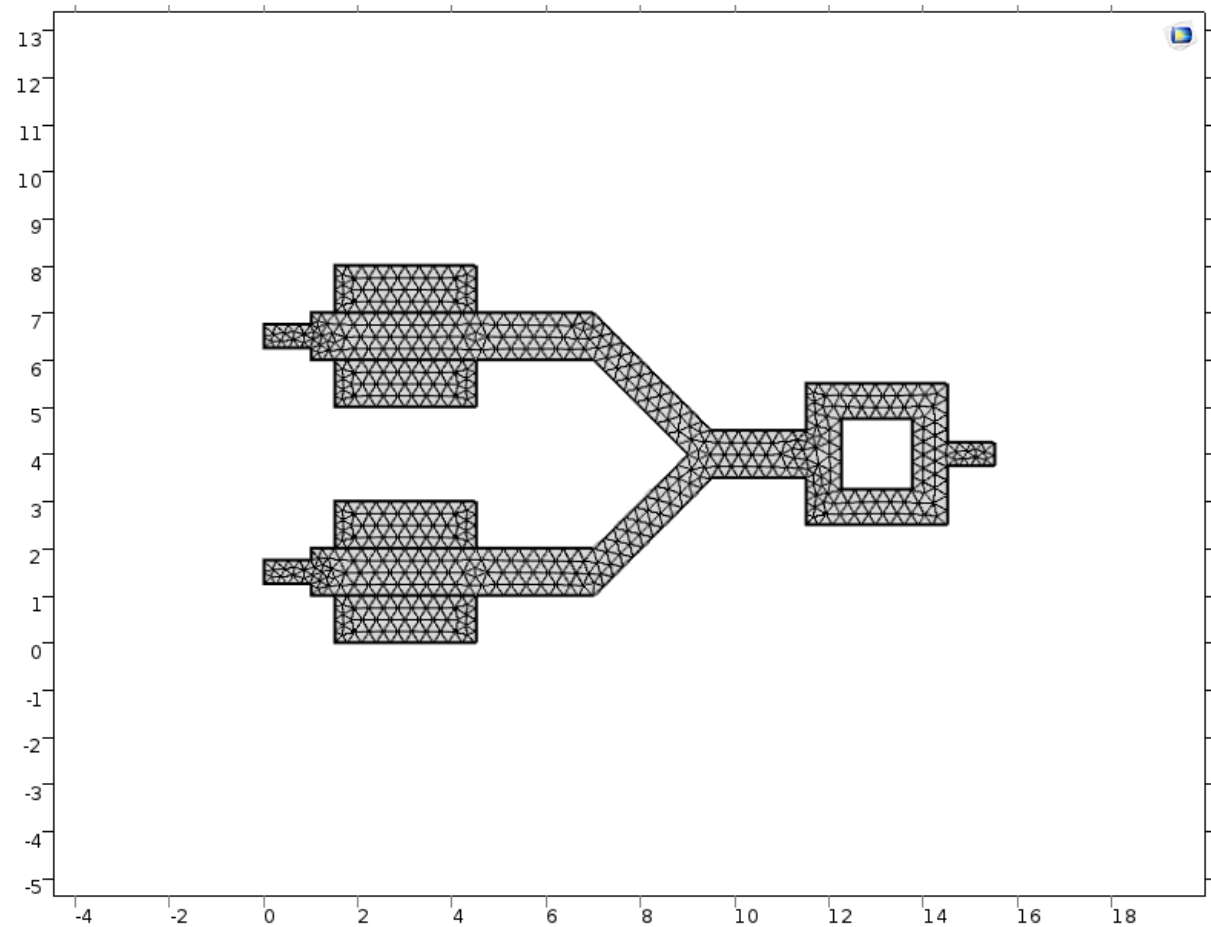
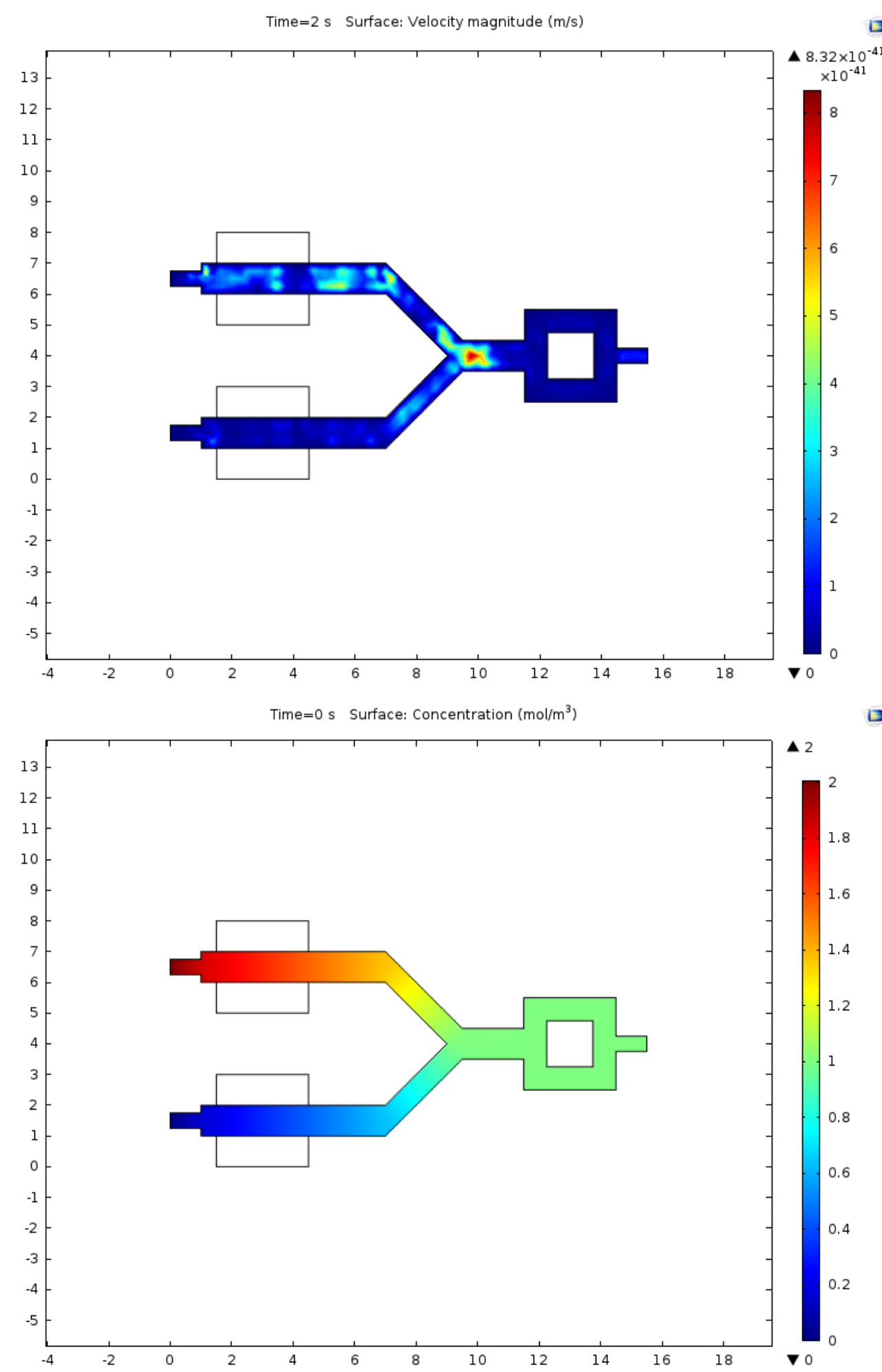


Figure 3:Schematic diagram of Lab-on-a-Chip device which is simulated by COMSOL. The 2D plot of the structure design.



The velocity and surface concentration result is showed as above.

Conclusions and Future Work

In this project, COMSOL simulation of a lab-on-a-chip glucose continuous sensing is proposed. The working principle of the device and fiber-optic SPR sensor are analyzed. Lab-on-a-chip device can handle sampling, reagent introduction, analysis and glucose sensing using a single tiny MEMS chip. In this device, it should integrat micropump, micrmixer and fiber-optic surface plasmon resonance sensor on a single chip. In the poster, COMSOL verify the overall function. The research will stay in upgrade. The micropump and micromixer still need to be design better. Also, how to enhance the accuracy of the SPR senor is still to be discussed. In the future, we will improve the design and verified with COMSOL, to achieve more detail process in the chip, eventually we can produce a prototype for real test, further to test the capability of this device in the real world.

References

- [1] Makaram, P.; Owens, D.; Aceros, J. "Trends in Nanomaterial-Based Non-Invasive Diabetes Sensing Technologies." Diagnostics 2014, 4, 27-46.
- [2] Li, D.; Yu, H.; Wu, J.; Yang, D.; Xu, K. "AN OPTICAL LAB-ON-A-CHIP SYSTEM BASED ON SPR SENSOR FOR CONTINUOUS GLUCOSE MONTIORING"